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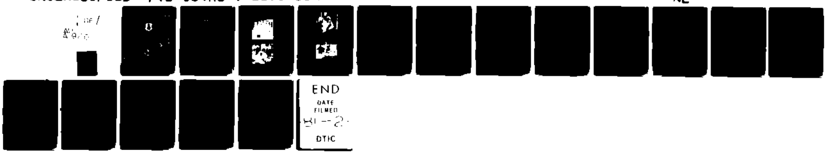

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FOREIGN TECHNOLOGY DIVISION

LASER LIGHT FIBER COMMUNICATION

by

Huang Dingguo

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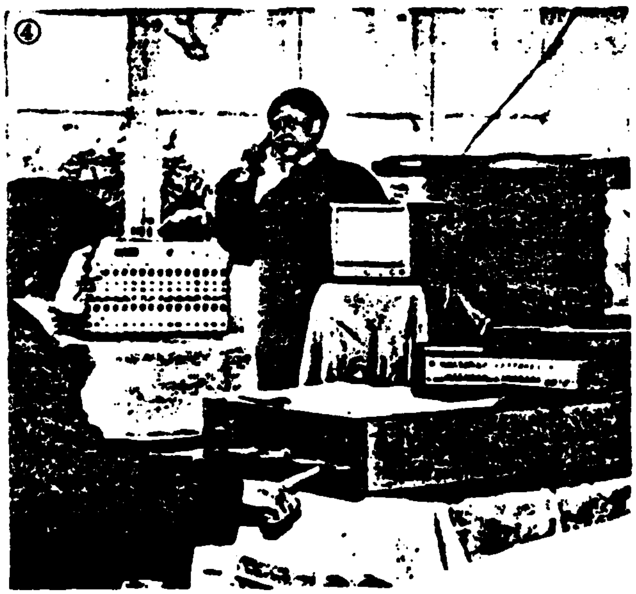
China's First Successfully Tested Photoconductive Fiber Communication System Indoor Combination Machine

1. Transmission television and telephone (photograph by Wang Zijin of the China News Agency

2. Conveyer writing telephone

3. Carrying out of telephotography



4. Transmission of data (aside from above mentioned, all photographs by Zang Zhicheng

LASER LIGHT FIBER COMMUNICATION

by Huang Dingguo of Wuhan's Posts and
Telecommunications Science Institute
of the Ministry of Posts and
Telecommunications

The use of light to transmit signals is not unfamiliar to the Chinese working people. During the Zhou dynasty, in about the year 2700 B.C., people began constructing beacon towers and using flames to transmit news. If an enemy attacked, then each joining tower would light their beacon to send a warning. This was ancient flame communication.

In modern times, people were already using simple light communications in warfare and traffic control systems. For example to maneuver ships, the navy carried out the formation of flash lamps; to conduct warfare, there was the coordination of movements of multicolored signal flares; at sea, there was the use of lighthouses in harbors; red and green signal lights at railway stations and traffic indicator lights at city intersections both used visible light for light communication.

The reason why these simple light communications had never developed was because the direction of emission of these types of natural light were disorganized, their frequency composition was complex, they were not easily controlled and they could not be used to transmit complex language signals and television image signals.

Our familiar radiotelephone communications use a single frequency radio wave to convey a language signal carrier wave. It is sent into space, is transmitted through a distance in space, is received by a distant receiver and the language signal which is obtained from the carrier wave reaches it's communication target. It can be seen that an important key in actual communications is the need for a single frequency electromagnetic wave as the carrier wave. Light and radio waves are both electromagnetic waves. Both possess all of the special characteristics of electromagnetic waves but the wave length of the radio waves is much shorter. From the electromagnetic spectrum chart on the back cover it can be seen that visible waves include red, yellow, orange, green, black blue and purple frequency light. Compared to the red light wave length longer infrared light and the purple light wave length shorter ultraviolet light all of them are invisible rays. In conventional communications, long wave, short wave, ultrashort wave, microwave and micron wave wave bands have already been used. To realize communication, it is necessary to find a luminescent source of a single pure frequency in the light wave range (in the wave bands of infrared light - visible light - ultraviolet light) to act as a light carrier frequency.

Science and technology have continually moved forward and in 1960 lasers were discovered. The appearance of the laser offered a new source of light for mankind. It's frequency is very simple, it's laser beam is very fine, it has a high degree of concentration of light energy in one direction, it has a strong directional, it's luminescence is great and it is easy to control. Because of these features, the application of the laser has been increasing daily and one of it's major applications is in the field of laser communications. Without a doubt, the laser has the most ideal carrier frequency required for light communication.

The most advantageous point of laser communications is that it's communication capacity is immense. Laser frequency is extremely high, within 10^{13} - 10^{15} hertz which is about 1,000 times higher than existing microwave communication frequencies. Theoretically, if each telephone communication frequency band is 4 kilohertz, the laser light frequency band energy capacity is 10 billion telephone lines; if the frequency band width of each color television is 10 megahertz, then we can use the laser for simultaneous transmission of 100 million television programs. Up to the present, other communication systems were unable to reach such a large capacity.

Why We Want to Use Light Fibers For Laser Communication

Initial laser communication testing was carried out in the atmosphere and transmission was the same as common radio reception. With two points and an illuminator set up for reception on the ground, then communication could be carried out. Yet, on the ground, the use of the atmosphere to carry out laser transmission communication had fatal weaknesses. It was greatly influenced by the earth's atmosphere and was very unstable. Because the laser's wavelength is very short (in the micron capacity), when transmitting in the atmosphere, it encounters the minute obstacle particles of dust, fog, rain and snow. This causes light to be scattered in all directions and attenuation to be great thus forming so-called "atmospheric scattering". The steam vapor, carbon dioxide and methane in the atmosphere will strengthen the light absorption power of certain wavelengths and greatly attenuate the light's energy. This is so-called "atmospheric absorption". All of this limits the distance of communication. Aside from this, atmospheric turbulence and changes in atmospheric temperature can cause light beam vibration, and birds and aircraft can also impede light beams thus causing suspension of communications. Because of this, laser atmospheric communications are only suitable for short distance motorized communication. People then need to give consideration to finding a conductive substance such as electric wire and electric cable to carry out wired elecric communications.

The long production struggle of the working class has pushed forward the development of science. Early, at the beginning of the eighteenth century, a Greek glass blower observed that light can be transmitted from the end of a glass rod to that of another and here no light was projected out from the rod. During the 1930's, there were those who developed very fine quartz glass fiber and first discussed it's principle of light transmission. After 1958, there were also people who used good translucent optical glass to make fibers and developed various endoscope signal pipes to be used for medical treatment. Yet, light attenuation for these glass fibers was very great and the lengths were only several tens of centimeters to several meters. Six years after the discovery of the laser, there were those who predicted that the use of high purity, small attenuation quartz glass fiber for light transmission could promote long distance laser communication. In 1970, there was a great breakthrough in the development of low consumption light fiber technology. This is a type of fine glass fiber which can conduct light and is called light conducting fiber or simply "light fiber". Some technical books also call it "light wave conducting transmission wire" or "light wave conducting fiber".

How Light Fiber Transmits Light Waves

People will ask, can light be transmitted along a winding light fiber? The answer is affirmative. All light fibers are composed of a core and wrapping layer of glass. The diameter of the wrapping is about 100-150 millimeters and the diameter of the core is about 50-75 millimeters. The diameter of this type of fiber is fine yet when compared to the commonly used wavelength of about 1 millimeter, the light fiber corresponds to the light's "wave guide". However, it is different than the screened metallic wave guide used in microwave communications and because of this, it is called "medium of light wave guide". When they were developed, all were made to have the light refraction of the core glass be somewhat greater than the refraction of the wrapping glass. We know that when light rays use a determined angle and reflect from an optical density (refraction great) medium towards an optical rarity (refraction small) medium, there is possibly produced a complete reflection on the juncture of the two mediums toward the previous broadcast. In this way, it is only necessary for us to control the angle of incidence of the light wave within a certain range and then the light wave can, in the juncture of the two mediums, continually produce similar mirror reflection of light and be transmitted from one end of the fiber to the other end. The angle on the left side of the back cover shows three types of differently structured fibers. Their major differences are that the distribution of refraction on the section is different. The first and second types of light fiber are the above mentioned use of the complete reflex broadcast structure. The first has a coarse core while the second has a fine core. The distribution of refraction of the third type of light fiber on the section is: the central place is the largest, along the radius the refraction gradually declines towards the outside and the outermost layer is the smallest. Thus, when the light wave is transmitted in the fiber core section it can automatically gather from a place of small refraction to the axis with great refraction. This type of fiber is called "self focusing fiber" and it is applied extensively in light communications.

The Light Fiber Communications System

In principle, structure and communications process, the light fiber communications system is similar to radio communications. The difference is that the transmitted signals are in a frequency of the light wave band of the laser and not the frequency of the relatively low radio waves. For this reason, the oscillation source, amplification, modulation, filtering of waves, transmission and reception measurement are all related to the special qualities of the light. Below we made in chart 1 a schematic diagram to explain the principle of the simplest light fiber communications system.

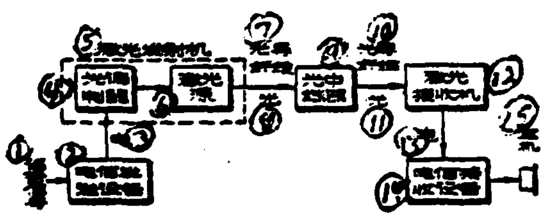


Chart 1

1. Voice signal
2. Telecommunication transmitter

3. Electricity
4. Light modulator
5. Laser emitter
6. Laser source
7. Light conducting fiber
8. Light
9. light relayer
10. Light conducting fiber
11. Light
12. Laser receiver
13. Electricity
14. Telecommunications receiver
15. Earphone

This is a schematic diagram of voice communication. The voice signal changes according to the strength of the sound by the common electronic device structured telecommunication transmitter. After it is amplified sufficiently, it is transmitted to the light source where it is modulated. Here, the light source is a light carrier frequency oscillator which is also a laser. This type of modulation is also called light modulation. It results in causing the stable unchanging light beam emitted from the light source to change according to the strength of the voice. In other words, it causes the light beam carried voice signal transmitted from the light source to form a modulated light frequency signal. There are two types of light modulation. One is direct internal modulation. It controls the changes in the light source electric parameter (electric current and voltage), causing the light beam emitted from the light source to change according to the strength of the voice signal. The other type is external modulation. On the outside section of the light source's emitted light beam is placed a crystal. The amplified electric signal (voice) is added on the crystal so as to change the crystal's optic qualities. In this way, after the light beam passes through the crystal, it changes according to the strength of the signal.

After modulation, the light frequency signal must enter into the diameter of the very fine fiber and using the method of direct aiming efficiency is very low. Generally, going through the small focusing lens of the lens coupler (see back cover) raises the coupling efficiency. After the light is transmitted a distance in the fiber, the strength of the light can attenuate. Because of this, in a long distance light fiber communications circuit, it is necessary to add many relays to amplify the light frequency signals so as to guarantee that the receiving end has sufficient strength.

Naturally, the light fiber communications system shown in chart 1 is only a chart of principle. Actual light fiber communications systems are multichannelled and have a large capacity. Because of this, it is necessary to add multichannel repeating apparatus in the system's transmitting end and on the receiving end add multichannelled branch apparatus. To attain greater communication capacity for our familiar microwave and coaxial cable communications system, we often use frequency repetition and time repetition to cause the different electronic signals of the many channels to be transmitted. In the same way, light fiber communication can utilize light frequency repetition, light time repetition and space repetition to realize greater communication capacity.

Special Points and Application of Light Fiber Communication

Examples of the special points of light fiber communication as compared to conventional electronic communication are as follows:

Large Communication Capacity. Based on initial estimates, a light fiber can simultaneously transmit 1 million 500 thousand telephone lines and 2,000 color televisions which is over 800 times greater capacity than the existing 1,800 line coaxial cable carrier wave communication. This is just the capacity of one set of fiber communications, and if one beam of several tens to several hundred fibers are gathered together to make a light cable, it's communication capacity will be even more astonishing and it's diameter will only be 1 to 2 centimeters. If we use the frequency repetition technique in one fiber again to transmit several wavelengths of light frequency signals, one fiber will then be able to act as several thus causing communication capacity to increase several fold.

Saves a Great Deal of Nonferrous Metal. In the present use of coaxial cable, each 1,000 kilometers uses 500 tons of copper and 2,000 tons of lead. According to estimates, the pulling of 1,000 kilometers of light fiber only requires several tons of kilograms of super pure quartz glass.

Resists Interference. What is transmitted in the light fibers are light waves that do not fear thunder and lightning attacks or receive interference from strong electromagnetic fields. It is a useful tool for strengthening telecontrol, telecommunication and the transmission of data in electrical engineering. Moreover, security is excellent.

Endures Corrosion. Light fiber is generally composed of quartz glass which is physically and chemically stable, does not fear moisture and corrosion, and can be used to make a sea-bottom cable and form long distance sea light cable communications.

Ability to Wind Freely. Light fibers are extremely fine and their ability to wind is very good. On the plastic on the outside, there can be constructed soft, pliable, firm and dexterous cable which can adapt to different terrains and the layout of long distance main communication lines.

The various special points of laser light fiber communication mentioned above give rise to totally captivating vistas for this type of communication. After large capacity laser light cable communication is realized, this will not only cause a major historical transformation in traditional electronic communications but moreover the integration of photoelectrical technology will greatly propel forward the development of new electronic technology.

As everyone knows, mankind is in the process of marching towards the modernization of information which demands increases in the amount of data and daily availibility. For example,in data transmitted by satellites, guided missiles tracking systems, computer centers and in various communication departments for industrial telecontrol, communications and transportation, astronomy and meteorology, commerce and banking. The quantity of work for these data communications is very large, their uses are numerous and the required frequency bands are also very wide. Existing conventional electrical communications are far from being able to satisfy the demands and only laser light cable communication can accomodate this type of development.

With large quantity wide frequency band light cable communication there can be a new flourishing in telephone communications: the number of inner city telephones can increase ten thousand fold; automatic dialing of long distance telephones between cities can be as convenient as inner city telephones; the use of light cables for television and telephone network transmission lines will not only cause the making of two party telephone calls audible but will also be able to make them visible; it can also establish a national color television broadcasting network so that people can select any location's television program the same as listening to the radio; it can also popularize the use of closed circuit television for study, medical treatment and consultation, holograms, technological exchange and industrial application.

The use of light fiber is also very suitable in spacecraft such as airplanes, naval vessels and artificial satellites and rockets. It can lower their weight and make them not susceptible to electromagnetic interference.

Development work on laser light fiber communications has proceeded quickly. Now, people have already made successful breakthroughs in developing a low loss light fiber wherein loss in light fiber transmission has decreased to under 1 db/kilometer. Many nations have begun experiments using light cable for the transmission of city television programs and digital telephones; the number of telephone lines has already reached 50,000 to 150,000 and relay distance has been extended from several kilometers to 50-70 kilometers. New style long wave semiconductor lasers suitable for light fiber low loss areas have also already been produced. In general, light cable communications are already on the eve of applicability and it will not be long before the realization of large quantity laser light cable communications.

The development of things has no limit and at present people are in the process of advancing research on imitating integrated circuit technology for integrated light paths. That is to integrate the laser, probe and various light apparatus on a very small base strip and matched with lower transmission loss, fibers with larger transmission capacity and the selection of suitable laser wave lengths, this will produce a second generation light cable communication system with larger communication capacity, longer relay distance and better performance.